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An Analysis of Cellular Telephone and INMARSAT Systems for Providing Radio Data Link Computer Communications for US Navy Vessels

by

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December 1993

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An Analysis of Cellular Telephone and INMARSAT Systems for Providing Radio Data Link Computer Communications for US Navy Vessels

by

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

This thesis examines radio frequency data link computer communications systems with emphasis on their potential application to ship/shore communications. Covered are two systems that experts believe hold the most promise for DoD application, International Maritime Satellite (INMARSAT) and cellular radiotelephones. An analysis of system capabilities, cost, and future potential is performed for each, and then the two systems are compared. In addition, a thorough discussion of the security issues for each system and final conclusions/recommendations are presented. The conclusions suggest that increased cellular radiotelephone usage vice INMARSAT by fleet units would optimize fleet readiness and improve supply system performance. Based on these conclusions, this author's recommendation is that all Navy ships be equipped with a cellular telephone system, while all aircraft carriers and amphibious aircraft carriers be equipped with both cellular and INMARSAT systems.

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I. INTRODUCTION

A. SYNOPSIS

The prime characteristics of the operating forces, their readiness, mobility, and endurance, prescribe the form of support which the Navy Supply System renders. The fleet is virtually always mobilized; only the tempo varies. It is the task of supply managers to provide, without failure, the material support required by the operating forces under all conditions of peace or war. This support must be provided at minimum cost for both the material itself and for the effort involved in supplying it [Ref. 1:p. A-8]. Consequently, Navy fleet supply support is based upon an organic level of supply and two echelons of resupply: the first echelon of resupply consists of the combat logistics force (CLF) ships and overseas bases; the second echelon of resupply consists of the supply centers in CONUS.

The job of supplying just what is needed, and without waste, is a demanding one. It requires management of an enormous quantity of items for which demand changes almost daily and the providing of these items to a changing number of customers at various locations around the world. Managing an economical supply system that provides for the customer's needs is a formidable task demanding the best executive talent and support equipment.

History has shown us that war can test the supply system in various ways depending upon the enemy and theater. For instance during World War II, supply effectiveness was obtained through

massive support operations. During the Korean War, we found our production base largely dissolved with little development of new weapon or supply systems. We were still able to provide supplies due to our large pre-war reserves, however we found out that large massive conflicts without ongoing production can quickly dwindle reserves to a risky level. The Vietnam War once again found us having to ship large amounts of war supplies to logistic stock points in the Western Pacific. Massive airlifts coupled with civilian contracted and military cargo ships were required to meet the enormous demand. The United States capability to produce and deliver the required supplies and equipment was a major influence towards the war's end. [Ref. 2:p. 218] Operation Desert Shield/Storm provided the opportunity for Department of Defense (DoD) logistic personnel to test the new logistic plans and supply channels developed as a result of these past experiences. Logistic support for the Gulf War was superb. [Ref. 3:p. 16]

Current world events have brought to light the need to develop a logistics support concept that utilizes radio frequency computer communications. The Gulf War and the associated burden of MINIMIZE, a condition where only high priority tactical messages are transmitted via military satellite, demonstrated the serious need of a communication system capable of transmitting supply, personnel, administrative, medical, engineering and maintenance information via means other than standard Navy communication channels. Commercial satellite and cellular telephone systems are both being reviewed for use in the future. The technological

advances made in the area of commercial satellite communications and cellular radiotelephones are having a dramatic effect on our planning process for future hostilities and peacetime operations [Ref. 4:p. 1].

The use of enhanced radio frequency computer communication systems is significant in that never before has the Navy been able to manage its secondary missions or support functions in near real time conditions. Supply Officers onboard Navy ships have long awaited the capability to exchange data with shore installations' computers while at sea, thus increasing their supply readiness and combat logistics capabilities. Current communication systems onboard ships do not lend themselves to non-tactical or administrative message requirements, especially during hostilities, due to the routine classification placed on them. More than half of all peacetime ship-to-shore message traffic in common-user channels is non-tactical and unclassified. [Ref. 4:p. 1]

Currently, PC-to-PC file transfer is not easily accomplished by existing communications suites' operating system formats. Various systems such as FLEETSAT, have been used by battle group commanders almost exclusively for tactical purposes, UHF circuits which are only line-of-sight are range limited, and HF circuits are too easy to track and pinpoint one's location. Therefore, in an attempt to overcome the short supply of voice and secure voice communication nets available for the administrative and non-tactical information, Type Commanders (TYCOMs) are outfitting their larger ships with commercial Satellite Communication (SATCOM)

terminals. International Maritime Satellite (INMARSAT) is currently the most widely used commercial satellite system available for Navy use. However, cellular radiotelephone is also being developed and tested as a possible alternative. The development of these modes of radio frequency computer communications is being spearheaded by the Space and Naval Warfare Systems Command (SPAWAR). This thesis will examine these alternatives in an attempt to determine which system would be most cost-effective and efficient in meeting the needs of the Navy and the fleet for exchange of support-related information well into the future. The current trend of reduced budgets and manning re-emphasizes the need for automated systems which provide accurate real-time information exchange between ships and shore activities while being capable of reducing man-hours per inputted transaction.

B. OBJECTIVES

The objective of this thesis is to provide an analysis of these two proposed computer data communication systems since the Navy is considering procuring, implementing, and maintaining one of them onboard ships and at Fleet and Industrial Supply Centers.

C. SCOPE

This thesis will focus on the above two of the many alternatives available for establishing secure, reliable data link communications between ships and Fleet and Industrial Supply Center computers.

For discussion purposes within this thesis, information referenced may come from sources which may be viewed as biased toward these systems. It should be remembered that the radio frequency computer communications program is an experimental program, and assumptions made or conclusions drawn by some sources may be changed as further developments and evaluations occur for these systems.

D. THESIS ORGANIZATION

Chapter I has provided an introduction and foundation for the scope of this study. Chapters II and III provide overviews of INMARSAT and cellular radiotelephone systems, respectively. Chapter IV will cover security issues and Chapter V will compare and contrast the two systems. Finally, Chapter VI highlights the conclusions reached in the thesis and outlines areas for further study.

II. INTERNATIONAL MARITIME SATELLITE SYSTEM

A. BACKGROUND

To understand where radio frequency computer communications is going, it is important to understand how it got where it is. This chapter will briefly examine the evolution of INMARSAT from its beginning to today and will show how the emergence of new satellite technology coupled with new computer systems has affected INMARSAT's use and role in fleet readiness.

Maritime mobile communications had always been affected by atmospheric disturbances, and satellites appeared to be an excellent way to overcome this problem. The International Maritime Satellite Organization came into being in 1982. It consists of three bodies, an Assembly, a Council, and a Directorate headed by a Director General. The Assembly is made up of representatives of all member states and meets every two years. It reviews the activities of all of INMARSAT, formulates general policy, and makes recommendations to the Council. Each member country has a vote in the Assembly. INMARSAT's Council functions as a board of directors, responsible for programs and the operation of the space segment. It meets three times a year and is comprised of representatives of the eighteen countries with the largest investment shares and four others elected on a geographical basis with due regard to the interests of developing countries. The top five signatories (member countries with an investment share of at

least 5%), measured in investment shares, as of 31 December, 1992 are listed in Table 1.

Table 1

INMARSAT'S TOP FIVE SHAREHOLDERS, 1992

Name	Percent
United States	25.0%
United Kingdom	12.8%
Norway	12.6%
Japan	9.2%
France	4.8%

Source: INMARSAT, Annual Review 1992, p.24.

COMSAT General Corporation of the United States is the largest user of the INMARSAT system and holds approximately 25 percent ownership in the international organization. Headquartered in Washington, D.C., COMSAT provides satellite and coast earth station services for ships at sea, off-shore oil platforms, and international land mobile applications virtually anywhere in the world via the INMARSAT system.

INMARSAT provides telephone, telex, low/medium speed data over telephone channels, facsimile, leased circuits for voice and high speed data, data communications, limited land mobile applications, group calls, and distress and safety communication services to shipping and offshore communities. Over 21,000 ships use INMARSAT

services. The number is expected to reach 35,000 by 1995 [Ref. 5:p. 52]. In the light of the introduction of the new small, low cost Standard C antenna, this number may rise even more rapidly.

Satellite capacity for mobile communications is currently leased by INMARSAT on eight satellites, four of which are leased in a primary operational mode. Two Marecs satellites are leased from the European Space Agency (ESA), and three specially equipped INTELSAT V satellites with maritime communications subsystems (MCS) are leased from the International Telecommunications Satellite Organization (INTELSAT). Back-up capacity on three Maritime Communications Satellite System (MARISAT) satellites is also leased from COMSAT General Corporation.

The investors own and operate the system's nineteen coastal earth stations which provide the interface between INMARSAT's satellites and national and international telecommunication networks on land. INMARSAT's coastal earth stations transmit to satellites on 6 Ghz and receive on 4 Ghz [Ref. 5:p. 52].

Ship antennas are purchased or leased by the ship's owners from manufacturers and suppliers of such equipment. Ship antennas are typically .85 to 2-meter parabolic antennas housed in a fiberglass radome and mounted on a stabilized platform which enables the antennas to track the satellite despite ship movement.

INMARSAT expects that all of its mobile services will grow with the introduction of smaller and less expensive earth stations. The advances made in the three generations of INMARSAT, from the $25,000 Standard A to the less-than-$12,000 System C, have greatly contributed to its increased usage.

B. EXISTING CAPABILITIES AND PHYSICAL DESCRIPTION

Since the launch of the first satellite, technology has increased the capability, durability, survivability and longevity of satellites to the point to where they are in orbit for periods up to ten years. Figure 1 [Ref. 6:p. 102] shows the various components of a recently launched spacecraft. Onboard processors can switch available power and bandwidths among six beams to apportion capacity according to traffic demand. During periods of low demand fewer bands and less power will be used to handle traffic. This variable power usage capability is one reason that the life of satellites has increased to twenty years. [Ref. 7:p. 22]

Satellites are launched in several orbital patterns, the most heralded and widely used is the geostationary orbit (GSO). GSO satellites are approximately 19,000 nautical miles above the equator and offer a number of advantages compared to non-geostationary circular or highly-elliptical orbits. A GSO satellite appears stationary to users on earth, which results in constant and predictable transmission parameters and simpler earth stations. Only three deployed satellites are required to provide global coverage of nearly all of the earth's surface.[Ref. 8:p.359]

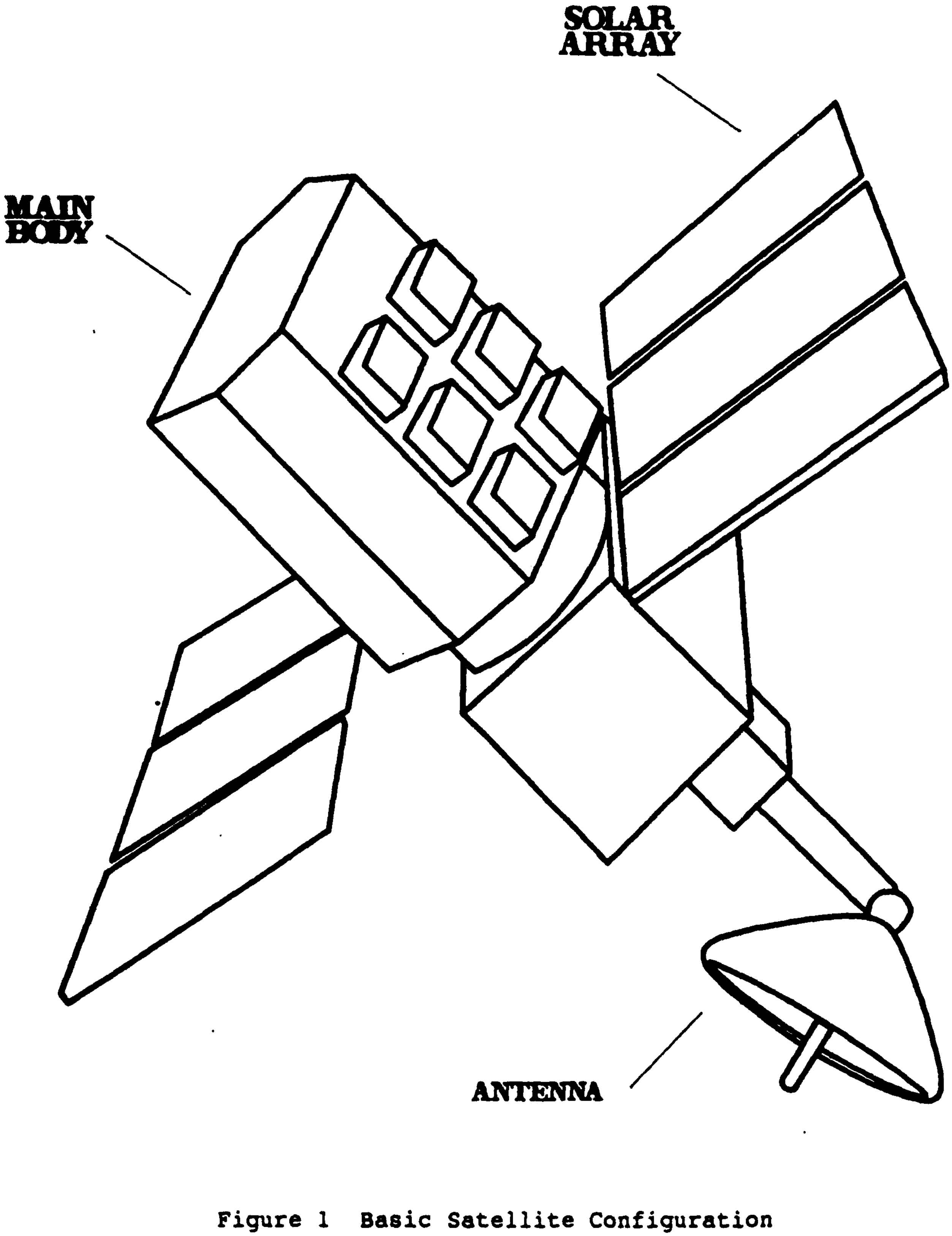

Figure 1 Basic Satellite Configuration

INMARSAT is now in the process of launching four new second generation spacecraft, known as INMARSAT-2. The first of these was launched on a McDonnell Douglas Delta-2 rocket in October, 1990; the second also was launched on a Delta-2 rocket in March, 1991. The remaining two are under construction and are scheduled to be launched with Arianespace on two Ariane-4 rockets. This generat of satellites will have approximately four times more capacity t the largest satellite in the present INMARSAT system. A contract has been approved by the INMARSAT council for the next generation of satellites, INMARSAT-3, which will be built by General Electric Astro-Space Division (now part of Martin Marietta) and scheduled for launch in the 1994-95 time frame.

Additionally, INMARSAT recently established a four-ocean region coverage by positioning two operational satellites in the Atlantic Ocean Region (AOR), one at 18.5° W (AOR-West) and the other at 18.0° E (AOR-East). The new western location provides full coverage over the North and South American Continents, and the new eastern location provides full coverage over Europe, the Middle East, and Africa. COMSAT has established additional facilities at the Southbury, Connecticut, coast earth station to access both AOR-E and AOR-W satellites. Coverage in the Pacific Ocean Region (POR) is provided by a satellite positioned at 180°E longitude and in the Indian Ocean Region (IOR) by a satellite positioned at 64.5°E.

The INMARSAT communications system is based on a frequency-division multiple-access (FDMA) plan which permits incremental increases in system capacity as traffic flows and provides the

capability for expansion to multiple shore stations operation. Any ship connected should be able to communicate directly with any shore station within a satellite coverage area. High-quality voice transmissions in both ship-to-shore and shore-to-ship directions employ single-channel-per-carrier frequency modulation. Because of satellite power limitations, threshold extension demodulator and compandors are used at the terminals to improve performance. These voice channels, with the compandors removed, can be used for high-quality data transmission at rates up to 9.6 kb/s [Ref. 9:p. 61].

The capability for telegraphy transmission is geared to providing real-time, full-duplex telex service over the satellite channels using, as far as possible, standard signaling techniques. Other data rates are accommodated by rate/alphabet conversion using facilities which are not part of the earth station. System access from ship terminals is by means of a random access "request" channel. When a ship wishes to originate a call, a short burst of information is sent to the earth station. A separate RF carrier is shared by all ships for this purpose. Request messages have the same modulation characteristics as Time Division Multiple Access (TDMA) signals and use common ship terminal equipment. In addition to full duplex 50-baud transmission, the chosen signaling techniques permit ship-to-shore simplex operation.

Methods for telegraphy transmission differ for outbound and inbound links. For the former, twenty-two 50 baud channels are time-division-multiplexed (TDM) and transmitted on a Coherent Phase Shift Keying (CPSK) modulated carrier at a data rate of 1200 b/s.

This carrier also contains an assignment channel which informs appropriate ships of incoming calls and automatically causes the ship terminal equipment to switch to the proper time slot (or frequency if voice is to be transmitted). On the ship-to-shore telegraphy link, a simple "open loop" TDMA technique is used. All ship receivers generate timing information from a portion of the TDM signal (TDM signal received by ships at all times); therefore, no ship-to-ship synchronization is needed.

Suitable allowances are made for burst-to-burst transmissions from different ships to account for differences in transmission times resulting from different ship locations. Each burst lasts for about 38 ms and there is an average time of 41 ms between adjacent bursts. The bursts are transmitted at a rate of 9.6 kilobytes per second so that each carrier accommodates 22 simultaneous 50-baud messages. [Ref. 9:p. 62]

The capacity of the system for civil maritime use is dependent on the extent of U.S. Navy usage. With full Navy service, the 1.5 Ghz radiated power is 20 dbw and the system has the following capacity in the shore-to ship direction:

* One voice carrier capable of supplying an equivalent subjective average signal-to-noise ratio of 28db;

* Two TDM carriers capable of providing 22 telex channels each with a bit error rate of less than 10^{-5}. [Ref. 9:p. 62]

C. SYSTEM CONFIGURATION

The basic INMARSAT system is diagrammed in Figure 2 [Ref. 4]. The coastal earth stations (CES), of which there are 19 worldwide, operate at C-band frequencies and communicate data between satellites and telephone networks. A coastal earth station costs its owners approximately 2.2 million dollars. The Navy would be required to pay a leasing fee, since they would not be buying the station, just using its capabilities. The ship earth stations, of which there are in excess of 21,000 worldwide, are operated in the L-band and are used, as the name suggests, to communicate between satellite and ship.

System configuration varies from system to system as shown in Figures 3 through 5 [Ref. 4]. Shore station communication electronics provides the capability for transmission and reception of voice and data signals and pilot tones which are looped through the satellite and used to compensate for frequency errors introduced by Doppler shifts and oscillator instabilities. The electronics also provide automatic connection of satellite circuits to terrestrial circuits while monitoring overall system performance.

Ship terminal equipment is divided into two parts: (1) an above deck RF portion consisting of an automatically pointed antenna, a pedestal and a receiver preamplifier, and (2) a below-deck portion consisting of an antenna control unit and the communications electronics needed for voice and data services. The power amplifier is used for both voice and data transmissions.

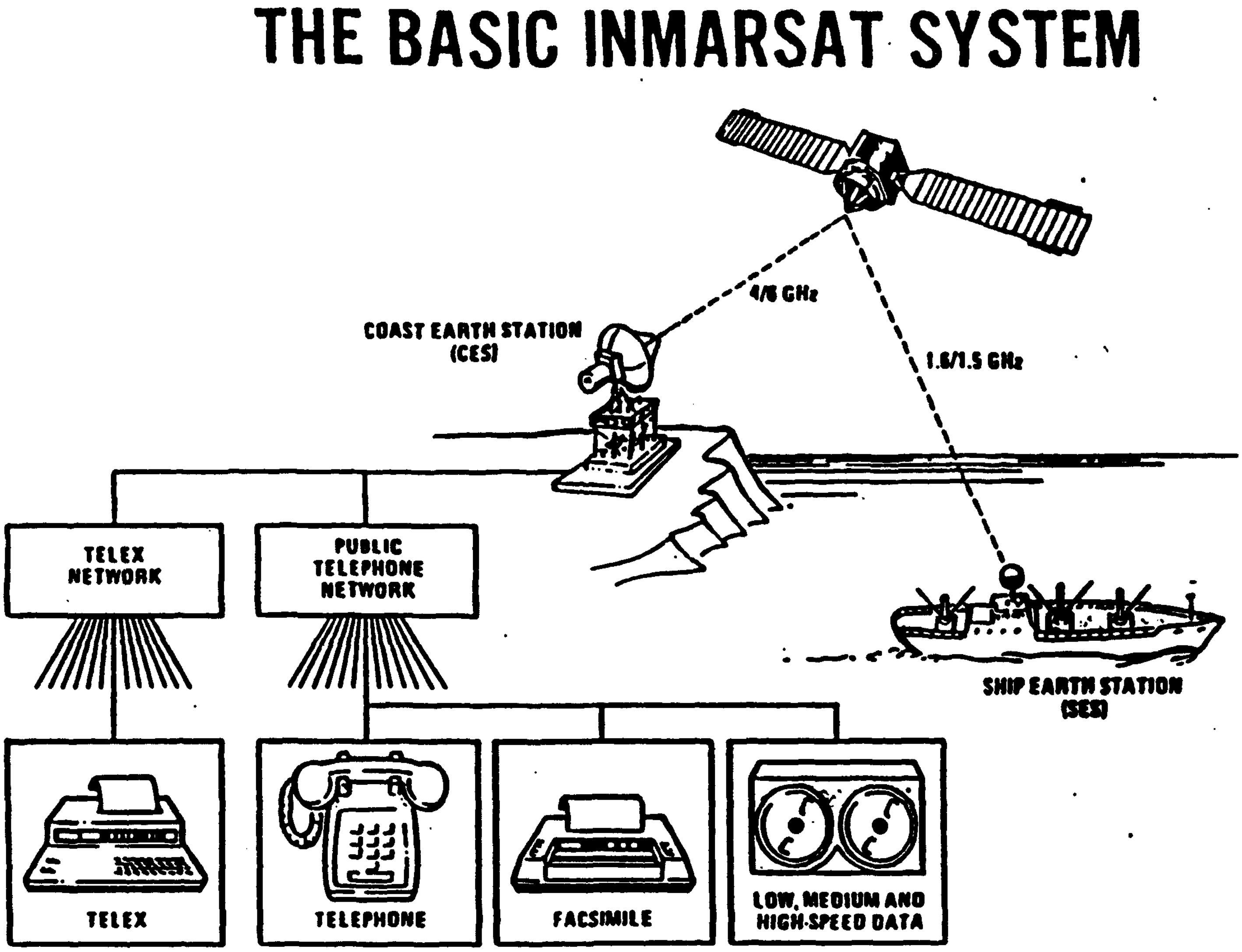

Figure 2 Basic INMARSAT System

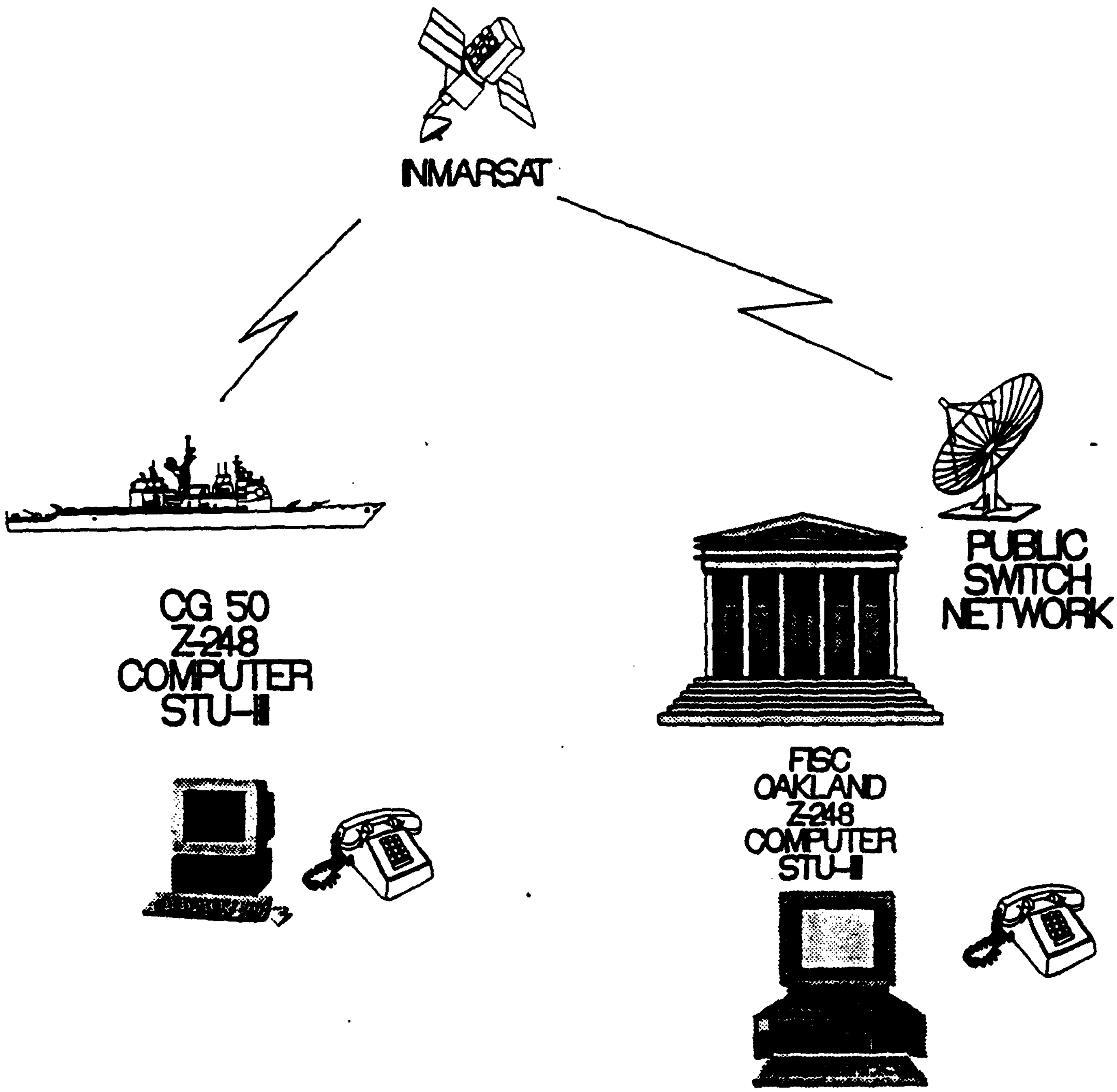

Figure 3 INMARSAT System Ship to Shore Mainframe

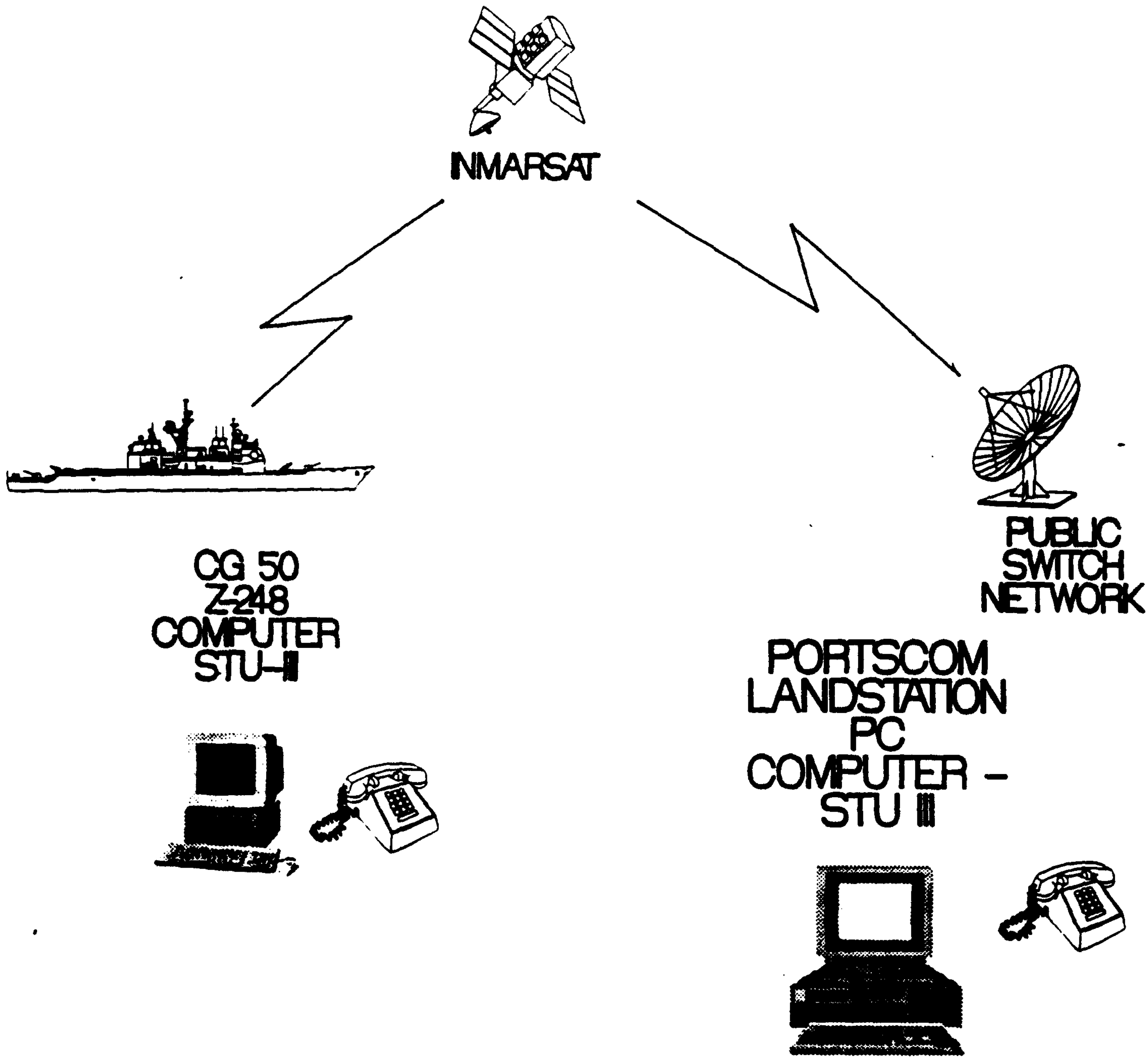

Figure 4 INMARSAT System Ship to Shore PC

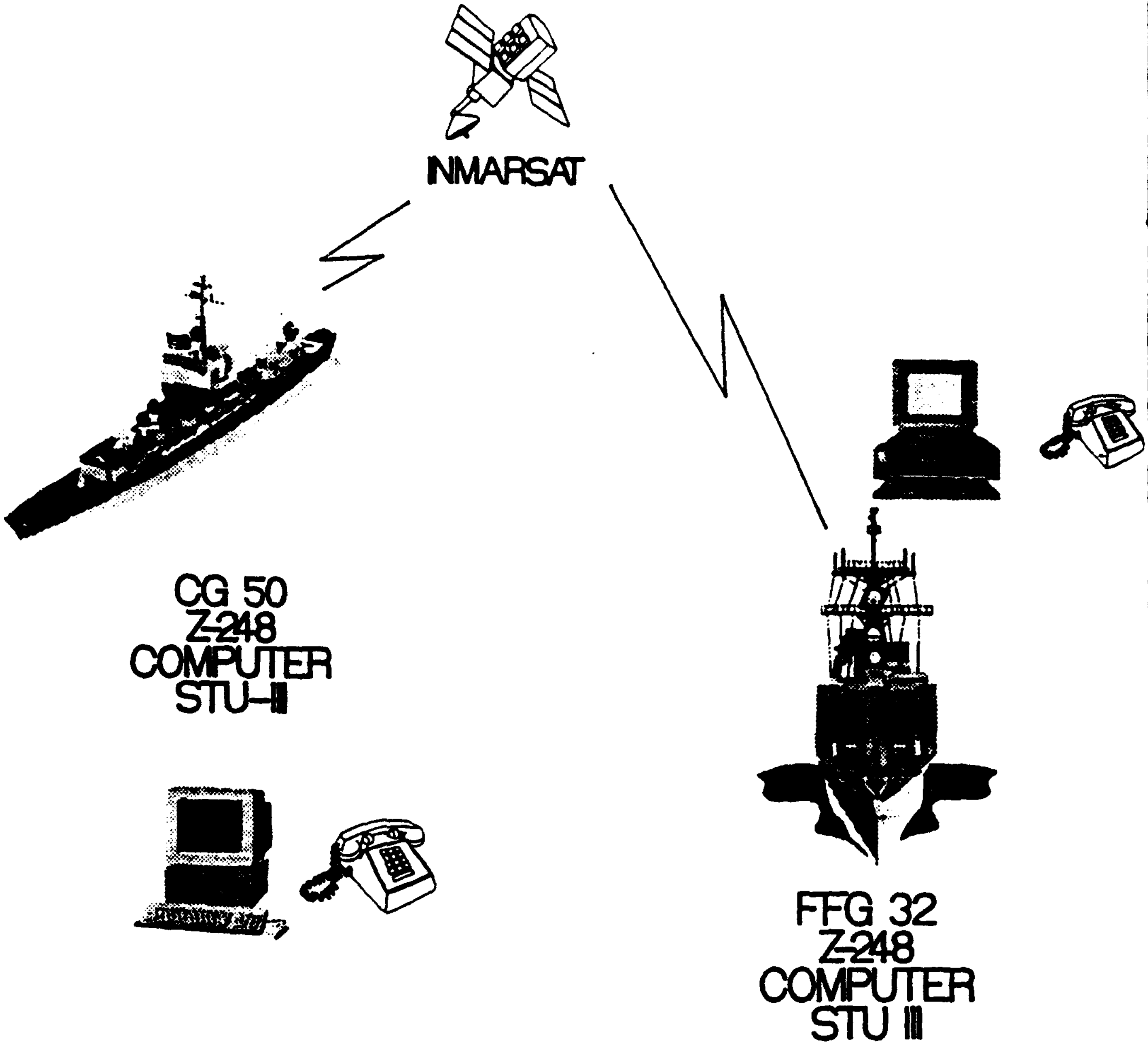

Figure 5 INMARSAT System Ship to Ship

Figure 6 [Ref. 10:p. 212] is a block diagram of the ship terminal communications electronics. These units are equipped with automatic features to ensure both operational simplicity and proper network control. One such feature is automatic recognition of messages addressed to the ship with automatic switching to frequencies and/or time slots upon command from the shore station. [Ref. 9:p. 61]

INMARSAT currently comes in four different configurations. INMARSAT-A is a highly flexible system that permits various grades of two-way voice, telex, data, and fax communication. This configuration uses a stabilized parabolic antenna that is about one meter in diameter, so its use in a mobile environment is generally restricted to larger ships. Costs for INMARSAT-A terminals and antennas are approximately $35,000. Voice communications through COMSAT land earth stations cost approximately $10.00 per minute to any destination within the U.S. and Puerto Rico. Calls to other areas are priced higher. At the end of 1990 there were over 15,800 INMARSAT-A terminals in operation. [Ref. 11]

INMARSAT-M is planned for introduction in 1993. The INMARSAT-M service will support low cost, lightweight mobile terminals with low power requirements, offering telephony and 2,400 bits-per-second data and facsimile services for both maritime and land mobile users. During 1990, the System Definition Manual for INMARSAT-M which provides the detailed technical specifications of the system was approved and distributed to industry and signatories. In July 1991, the INMARSAT Council selected a voice

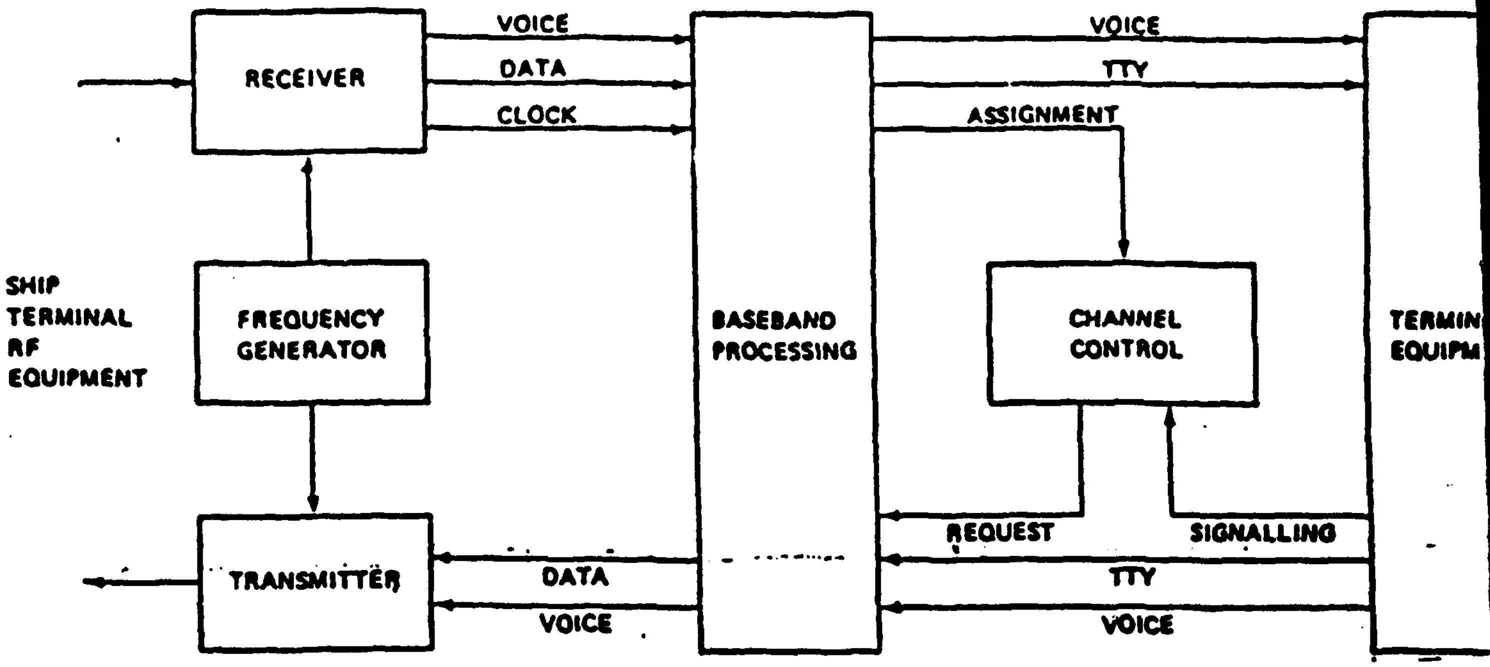

Figure 6 Block Diagram of Ship Terminal Communications Electronics

coding technique developed by US-based Digital Voice Systems, Inc. for use with the system. [Ref. 12:p. 12]

INMARSAT-B, to be introduced along with INMARSAT-M in 1993, is an advanced digital service using a new design of ship earth station aimed at offering a wide range of services such as telephone, telex, and facsimile at a rate of 9.6 kilobits per second and data at a rate of up to 16 kilobits per second. The new terminal specifications take full advantage of advances in satellite communications technology and will make more efficient use of the L-band frequency spectrum. Although INMARSAT-B will offer services similar to those provided by INMARSAT-A, COMSAT will continue to support INMARSAT-A until at least 2005. [Ref. 13:p. 13]

INMARSAT-C is a low-cost, two-way store and forward packet data system which uses a small omnidirectional antenna. This permits INMARSAT-C to be easily installed aboard small vessels and to be used for remote monitoring and control. Introduced in 1989, its costs ranged from $4000 to $6000 for a basic INMARSAT-C terminal in 1991. Depending on the options (such as personal computer, navigation receiver, etc.), costs for INMARSAT-C terminal could go as high as $12,000. Costs for INMARSAT-C message and data transfer via COMSAT coastal earth stations are expected to be approximately $1.05 per kilobit (125 bytes) from a mobile station to a base station. Base station to mobile messages will cost around $1.25 per kilobit. A 256 byte data report message from a mobile unit is expected to cost $0.10. These costs include movement via a packet-switched network anywhere throughout the

Atlantic, Pacific, or Gulf Coast states and Puerto Rico. Charges to other areas are higher. Additionally, no monthly subscription fees are anticipated. At the end of 1990 there were approximately 2400 terminals in operation.

INMARSAT-C terminal costs are reduced by using a small lightweight omnidirectional antenna and relatively low power digital packet transmissions. As shown in Figure 7 [Ref. 10:p. 375], the data-circuit terminating equipment (DCE) consists of the antenna, transmit, receive, and associated control electronics. The DCE, which interfaces with the satellite network, is connected via standard input/output (I/O) ports to the user interface or data terminal equipment (DTE) [Ref. 10:p. 374]. DTE can be laptop or standard-sized personal computers, ASCII terminals, printers, and custom "black boxes" for data interchange. Terminal position information can be automatically provided by an external navigation receiver, such as Loran-C, Transit, Global Positioning System, or other equipment which has a built in I/O port. The DCE and DTE together make up a mobile earth station (MES). [Ref. 14:p. 4]

INMARSAT-C terminals operate in the L-band. They transmit on 1626.5 MHz to 1646.5 MHz and receive from 1530 MHz to 1545 MHz. Tuning is in increments of five KHz. Time-division multiplexing (TDM) and binary phase shift keying (BPSK) modulation are used. Forward error correction (FEC) and 16 bit-packet data checksums are used to ensure correct message reception. INMARSAT-C terminals have unique electronic addresses and incorporate Enhanced Group

INMARSAT - C
Mobile Earth Station (MES)
Block Diagram

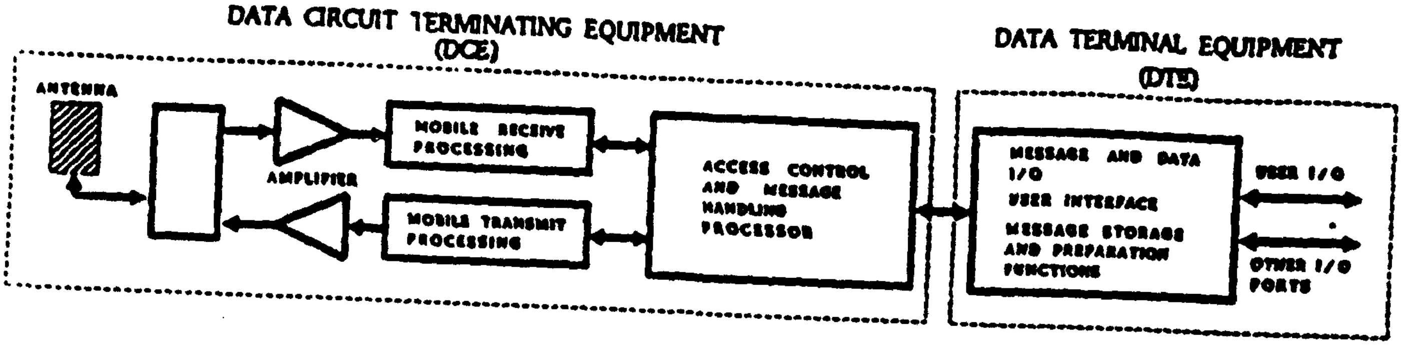

Figure 7 Mobile Earth Station Block Diagram

Call (EGC) functions. Enhanced Group Call allows messages to be broadcast globally, to specific ships, or to ships in a specific geographical area and is available via both INMARSAT-A and C. The EGC system supports INMARSAT's Safetynet™ service which provides for broadcasts of global, regional or local maritime safety information, navigation warnings, meteorological forecasts, distress alerts and other urgent information. Polling commands can also be used to initiate a mobile terminal position or data report. [Ref. 12:p. 390]

The system proposed for the United States Navy will employ satellite hardware currently in use in space and on the ground. Units preparing to operate using INMARSAT will have to purchase the necessary above and below deck equipment using funds from their ship's operating budget (OPTAR). Average installation time for the entire system should be one to two days. The above deck portion is a satellite antenna which is housed inside a radome. Ships will need to have a hollow mounting stand fabricated for the radome. A gyro connection will be necessary for correct antenna tracking or a flux gate compass is available from the system manufacturer. After the designated installation site has been identified, pre-cut cables will be manufactured for easier and timely installation onboard ship.

Below decks the ship will have to purchase or have available for dedicated service the following equipment for communicating and interfacing with other INMARSAT users:

* MS-DOS IBM or compatible personal computer

* A Hayes compatible modem with minimum baud rate of 2400 BPS
* Latest version of communications software for Personal Computers
* STU-III for security
* Central Processor Unit/Audio Processor
* Splinter unit for controlling signal input
* Telephone(s)

Units are modular in construction and have extensive self-test capabilities for quick corrective maintenance, when required. Operators can monitor the status of all system functions, isolating problems to the individual circuit board. The most critical and/or high usage spare parts can be easily carried onboard and should pose no problem for repair or replacement by technicians in the ET/RM rating.

A 5 April 1991 CNO guidance letter on ship-shore non-tactical information transfer named SPAWAR as the program manager and OP-94 (now N-6) as the program sponsor. The guidance called for an open architecture system which is transparent to the content of the information being transferred. INMARSAT will play a key role in the architecture. With new modes of information transfer increasing in use, there is growing evidence that non-tactical communications will require its own path which will be dependable even during crisis operations.

D. TEST AND RESULTS

Under OPNAV tasking, in March 1991 the Naval Electronic System Engineering Center (NAVELEX) in Vallejo, California, conducted

tests to evaluate ship to shore communications over INMARSAT. The objectives were to identify functional candidates for transmission, evaluate electromagnetic interference (EMI) and electromagnetic compatibility (EMC) of the system and to analyze anomalies encountered. Among the four ships used in the test, error free transfer of approximately 1,850 files was achieved at various baud rates up to 9600 [Ref. 4:p. 17]. The findings were:

* that INMARSAT is not a source of EMI/EMC interference as it was believed to be;
* that INMARSAT is resistant to interference from other systems;
* that the average compression ratio was 72 percent using commercial off-the-shelf software; and
* that the largest file transmitted was 7.4 megabytes, compressed to 1.3 megabytes and transferred in 88 minutes at 4800 baud.

The test results validated the pier-side support concept as a means to maintain up-to-date inventory status. The high data transfer rate coupled with the INMARSAT system availability in port would allow supply officers in port and underway the luxury of doing online stock checks without any human intervention at the Fleet and Industrial Supply Centers (FISCs). Ships, while moored in port, have very few landlines available to them; this system setup has enormous potential for such users in that data can be accessed without impacting the landline availability.

In addition to supply documents, several faxes were received

by one of the test ships and pay documents were transmitted to Defense Financial Accounting Service (DFAS-Cleveland), who endorsed the potential for INMARSAT to improve both the timeliness and accuracy of sailor's pay records. The following comment was made by Navy Finance Center upon completion of the INMARSAT test:

> Navy Finance Center recognized potential to improve both timeliness and accuracy using INMARSAT. Present comm system generates errors resulting in delays in proper payment of 1200 service members per month.[Ref. 1:p. 15]

The system configuration utilized during the test is displayed in Figure 8 [Ref. 4]. Various test ships equipped with the shipboard non-tactical automated data processing system (SNAP) and uniform micro computer disbursing system (UMIDS) were monitored to record capabilities in transferring MILSTRIP, payroll and administrative information respectively.

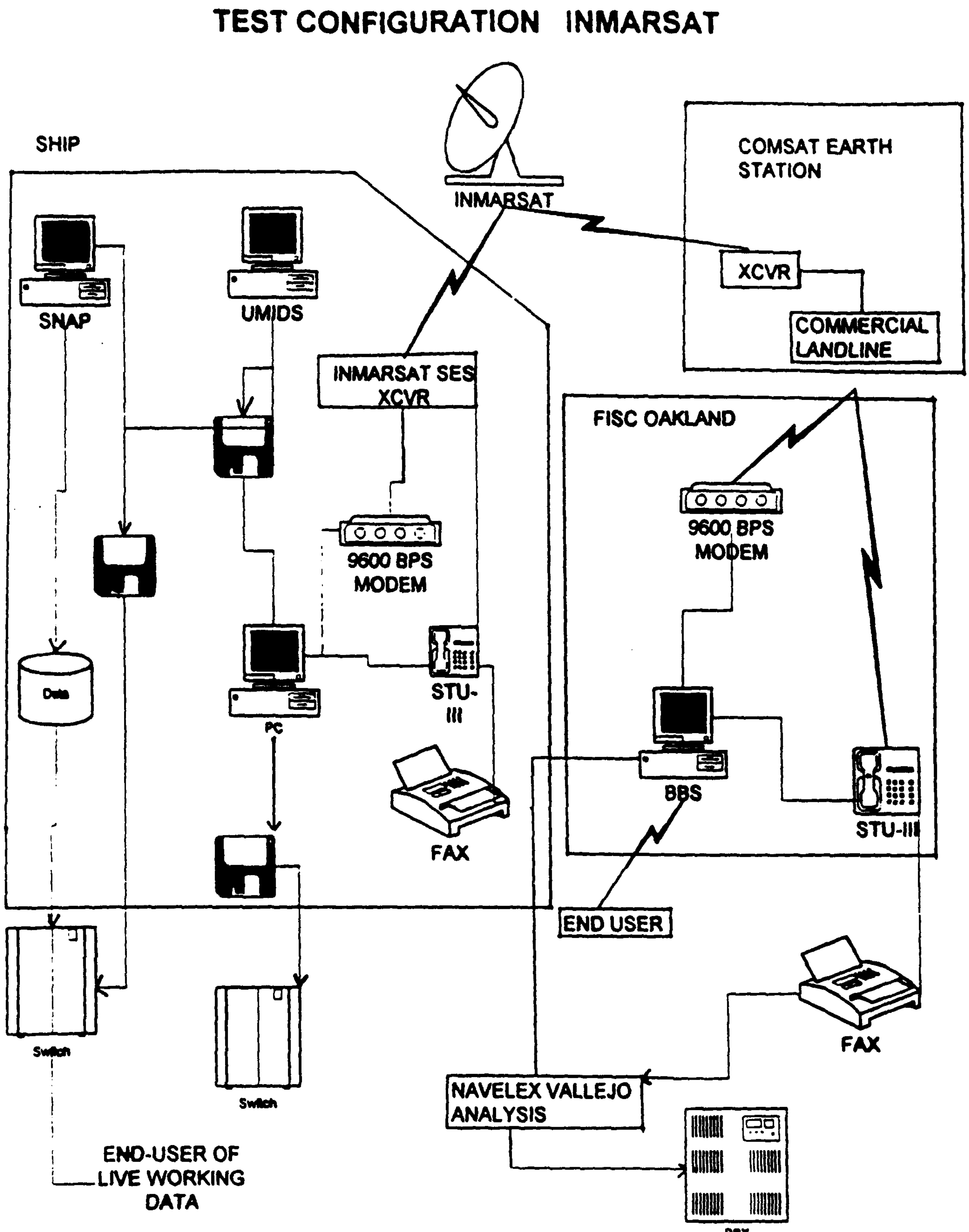

Figure 8 INMARSAT Test Configuration

III. CELLULAR RADIOTELEPHONE

A. BACKGROUND

The cellular radiotelephone industry is a relatively new and dynamic industry developed to provide more efficient, superior quality and higher capacity mobile telephone communications than either traditional mobile radio or mobile radiotelephones. Despite the commercial youth of this industry in the United States (less than 8 years) basic cellular technology is nearly 18 years old. Although cellular technology was originally designed for mobile voice communications, the industry is actively developing and pursuing additional applications, such as fixed cellular applications in specific situations as well as the transmission of data over cellular networks, which is where Navy interest lies for future uses.[Ref. 15:p. 1]

B. DESCRIPTION AND NETWORK CAPABILITIES

The cellular concept refers to a fully automatic, high capacity telephone system capable of serving mobile, portable and fixed subscribers over a wide area, based on the ability to reuse frequencies through a process known as hand-off. In a cellular network, an area is subdivided into smaller regions, or cells, each served by a low power radio transmitter that must be placed in a particular location for optimal radio transmission (cell site). Each cell site transmits signals to, and receives signals from, cellular units within its range (cell). The cells form a network coordinated by a separate, highly sophisticated switching office that automatically routes calls to particular cell sites in order

to maintain the strongest available signal and provides interconnection with the public switched telephone network. [Ref. 15:p. 59] Figure 9 [Ref. 15:p. 63] illustrates a typical land based cellular system. Although each subscriber unit has a home system, it may be used on other cellular systems. This is known as "roaming". A diagram of the roaming concept is provided in Figure 10 [Ref. 15:p. 270].

As is prevalent in other types of communications systems, the heart of every cellular radio system is the switching equipment. The mobile telephone switching office (MTSO, sometimes referred to as mobile telephone exchange, or MTX) manages all cell site operations and is the interface between the cellular network and the local and long distance public switched telephone network. Links from the MTSO to the cell sites can be analog or digital, and use coaxial cable, fiber optics, or microwave transmission facilities in any combination. Maintenance and administration of all cell sites in a system are also centralized at the MTSO. Functions of the MTSO include cellular network management, network diagnostics and hand-off control between cell sites. Radio channels are divided into voice channels and control channels. Information necessary to originate and receive calls is transmitted over the separate control channels between the MTSO and the cell sites that make up the system. [Ref. 15:p. 9]

When originating a call, the subscriber enters the number to be called and then presses the "send" button. The required

DIAGRAM OF A CELLULAR SYSTEM

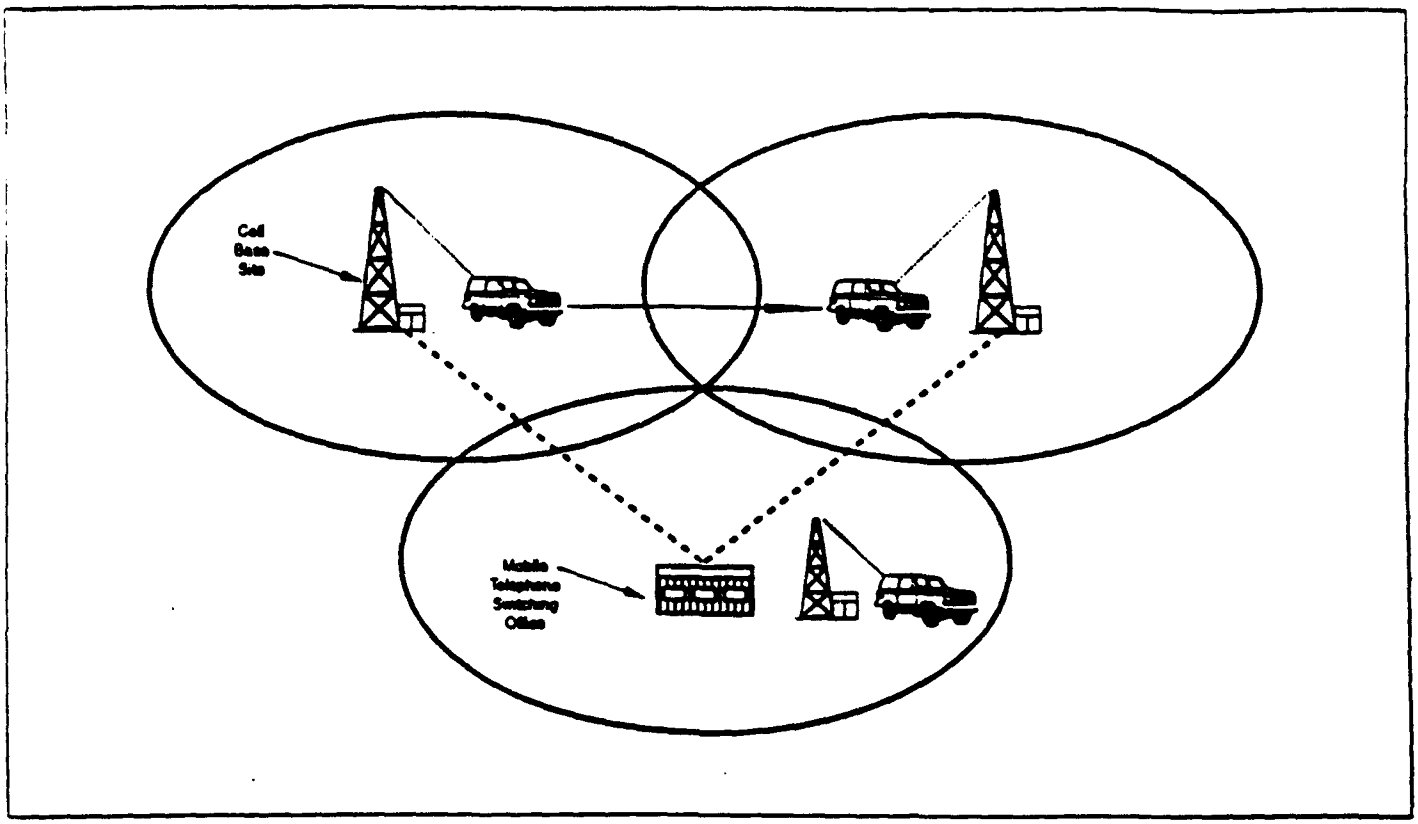

Figure 9 Diagram of a Cellular System

DIAGRAM OF ROAMING BETWEEN CELLULAR SYSTEMS

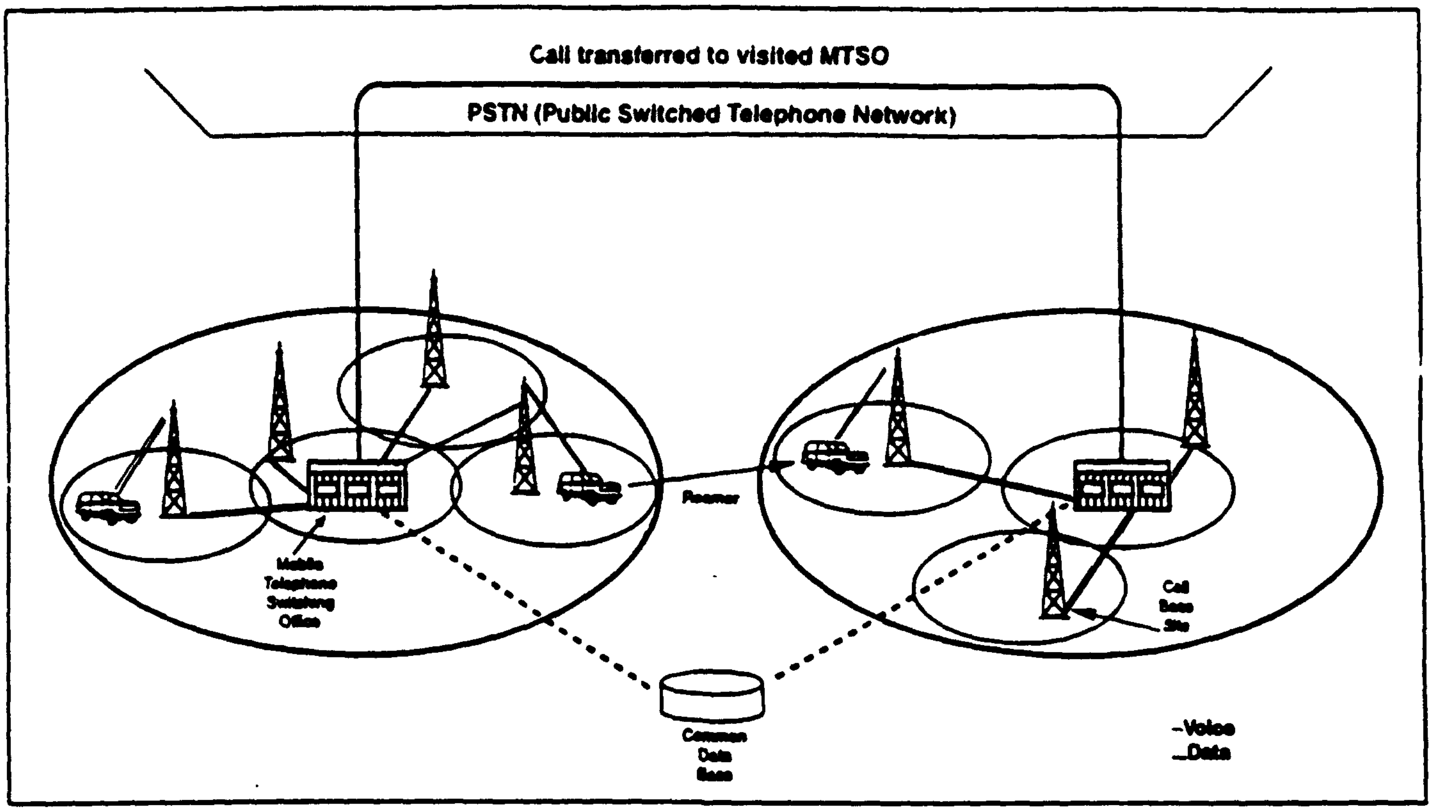

Figure 10. Diagram of Roaming Between Cellular Systems

telephone number, the mobile's phone number and serial number are sent to the local cell site on the reverse signaling channel. The serial number is used to help identify calling units for billing purposes. It should be noted that, when switched on, the subscriber unit monitors the cell site signaling channels in its vicinity and locks on the strongest. The cell site receiving the information forwards it to the cellular switch while at the same time "advising" the subscriber unit of its assigned voice channel. The switch processes the call into the landline network and connects the selected trunk to the cell site link associated with the designated voice channel. Figure 11 [Ref. 10:p. 237] describes the basic cellular system control functions. [Ref. 15:p. 25]

During the course of a conversation as the mobile subscriber crosses a cell boundary, control of the subscriber unit's call is automatically transferred from cell to cell as appropriate to maintain the continuity and quality of the transmission. This process of call transfer between cell sites is called "hand-off." [Ref. 15:p. 269] When the signal strength between the assigned cell site and mobile unit drops below a predetermined level, the cell site controller notifies the mobile telephone switching office (MTSO) and the hand-off sequence begins. The mobile unit is automatically routed to the appropriate base station with the strongest signal. On command from the MTSO, the locating receivers at each of the adjacent cell sites in the system begin monitoring for foreign frequencies. The MTSO then selects the cell with the strongest signal and assigns an idle channel frequency at the new

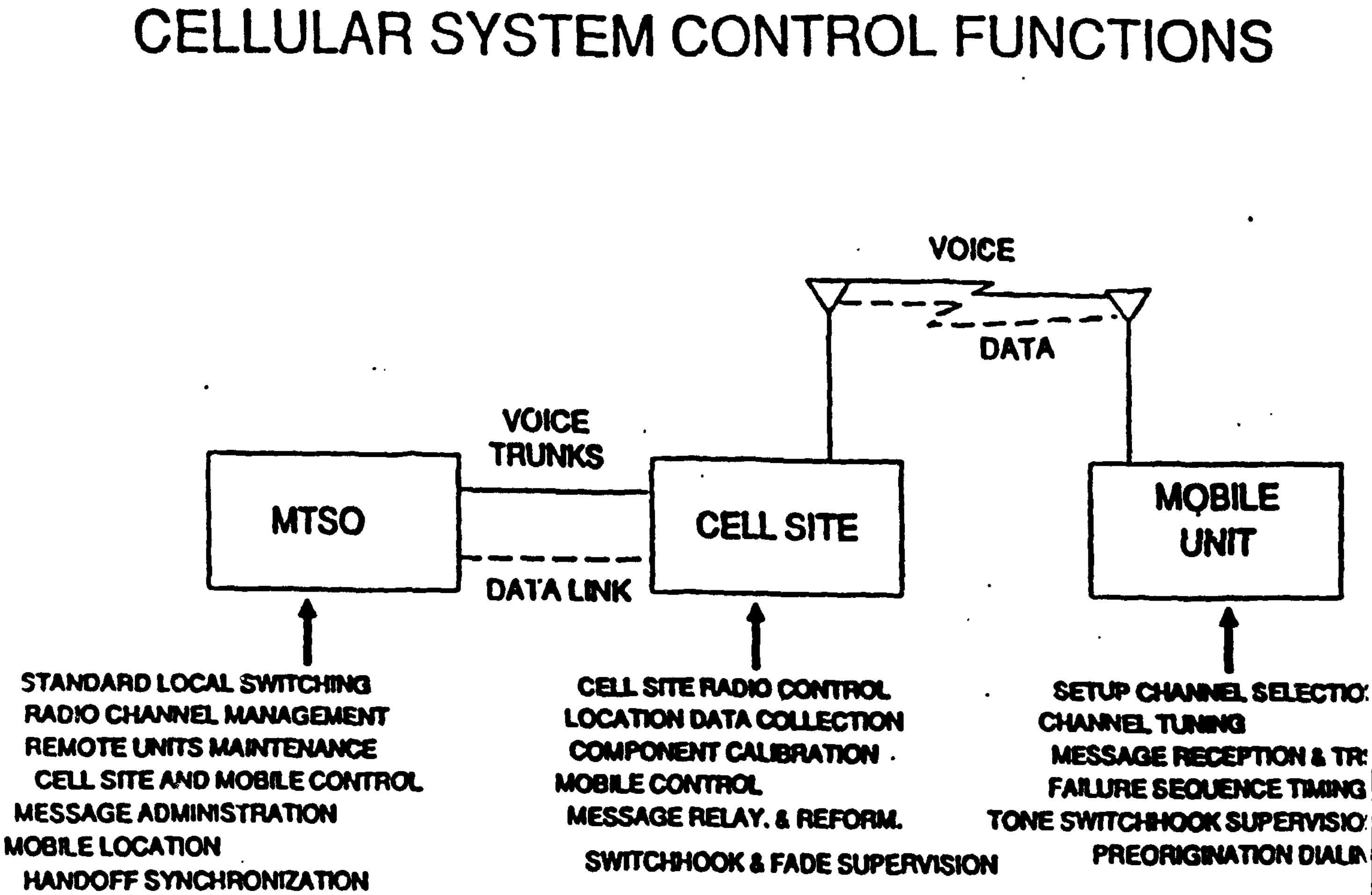

Figure 11. Diagram of Cellular System Control Functions

cell site. It then commands the cell site to activate that channel and advises the subject mobile unit to return to that selected frequency. When the cell site signals the MTSO that the former frequency is now idle, the MTSO switches the transmission path, completing the hand-off process. During hand-off, "dead-times" of a half second or more are common and while these dead times go virtually unnoticed in voice calls, they represent carrier drops to data signals and can cause the modem to "hang up." Cellular modems must anticipate this problem and compensate for it by "holding over" the call through the hand-off from one cell site to another.[Ref. 15:p. 275]

The system proposed for use by the Navy will consist of the same computer hardware required of the INMARSAT system plus the following items to control the cellular network:

* Base Station Control and Radio Frequency Equipment
* Marine Antenna

Manpower and spare parts support is minimal and consistent with that previously discussed regarding INMARSAT.

C. PROPOSED NAVY SYSTEM

The system proposed for Navy use by the author is very generic and allows for introduction of new hardware as developed. The system would consist of a Mobile Base Control Unit and Radio Frequency Equipment, marine antenna, IBM compatible personal computer, secure telephone unit (STU-III), one MTSO per battle group plus any required off-the-shelf software. The system would operate in conjuction with existing coastal cellular systems when

in close proximity to land or when in battle group formations not exceeding 30nm from the unit with the MTSO installed.

D. TEST AND RESULTS

Testing of the use of cellular radiotelephone for transmitting voice and data information has been successfully conducted both in special test exercises and in real world applications. A test conducted off the coast of South Carolina, utilizing the USS R.G. Bradley (FFG 49) and the Charleston Centel system in September 1991 demonstrated the range and capabilities of the shipboard cellular system. [Ref. 4:p. 59] The test showed that voice and data calls were possible for both ship-to-ship and ship-to-shore. Maximum ranges for each method were 30 nautical miles and 45 nautical miles, respectively.

Operation Desert Storm demonstrated under real world conditions the value of having this setup available for transmitting unclassified, non-tactical logistic data. [Ref. 3:p. 27] Cellular communications were mainly utilized to communicate ship-to-ship freeing up tactical circuits for other use. Currently ships are operating on both coasts communicating with Naval Supply Centers, Defense Finance and Accounting Centers and transmitting and receiving MILSTRIP data, payroll data and general administrative information. Ship Supply Officers who have cellular capabilities available to them when in port and on local operations have never been so well informed of outstanding requisition status due to the availability and accessibility of this system with FISC computers and customer service

personnel.[Ref. 16]

IV. SECURITY

The primary information both transmitted and received via the two communication methods would be unclassified. However, the need may arise when information of a confidential nature associated with a movement report (MOVREP), CASREP, or in port visit may have to be transmitted due to operational requirements. In this case it is better to have the necessary security in place to allow one that luxury, as opposed to having to use another onboard communication channel or hold the message until a more secure method of transmission is available. In this chapter we will discuss how much security is enough, and a few of the security options available for use. Let's begin with a look at the degree of security required for our proposed systems.

A. HOW MUCH SECURITY IS ENOUGH

How safe any proposed system actually is depends on both the environmental and security safeguards in place. The computer hackers of the world have shown that no safeguard or combination of safeguards can guarantee that data is 100% safe in such a system. Any attempt to even approach this figure utilizing present technology almost ensures that a system cannot be easily used. At the other extreme, the most user friendly system would exhibit great vulnerabilities. What every system security policy should ensure is a balance of these two extremes to a degree commensurate with the value of data to be protected.

One method for specifying how much security to provide for a system is the "Prudent Person Rule" [Ref. 16:p. 171]. The "person"

is that individual given responsibility for an organization's security. "Prudent" refers to his selection of the same safeguards in use by "most" of the other organizations in that industry. Supposedly, a loss occurring after such safeguards are in place would not be blamed on the prudent person but would instead be marked off as unavoidable.

Another view of how much security is enough centers on the assumption that the potential penetrator is a "reasonable man" and would not expend more resources on obtaining data than could be derived from having it [Ref. 16:p. 53]. Here data value is "approximated" (a judgement call) and security controls are increased only to that point where the "reasonable man" would give up attempts at access (a judgement call). This view's drawback is that data of low value to an outsider may be critical to an organization's continued health, and such data needs protection from accidental or malicious destruction.

For most day-to-day users of a system "enough" security is whatever allows one to get a job done in peace. Many users would probably consider no controls adequate. It is thus the responsibility of management to ensure that the user knows what this could mean. While user opinions may be valuable in defining just what interface a security control should assume, they should not be relied on to pass judgement on the appropriateness of specific controls.

No one criterion should be relied on in determining the degree of security to employ. Instead, it appears the best policy is to

combine attributes of several criteria. First, it is essential that data value somehow be determined; that is, value, not only to an outsider, but to the firm's operation. Next, all potential safeguards, both physical and administrative, should be identified and costed out. There is nothing wrong with reviewing what other organizations are doing (if the information is available) so long as innovative approaches are not ruled out.

System utilization may be entirely within a local operating area or cover vast distances in open ocean operations. Its communication links can be user-owned cable, leased lines, and voice dial-up. Domestic systems via commercial carrier, including value-added systems, greatly increase security problems. Unless private lines are used, data are transported totally by vendor media. This may be a plus where packet-switching systems route various pieces of information via different circuits, but it is a drawback where satellite transmission is concerned. Satellites provide the least degree of data security because uncovered/non-secure transmissions may be intercepted by anyone in the area with an appropriate antenna.

B. SECURITY OPTIONS AVAILABLE

Available security systems fall into five major categories. They are:

* host resident-based security software,
* encryption devices that encode the data before transmission and decode it upon arrival at its destination,
* call-back systems that call-back preprogrammed phone

numbers,

* hand-held password generators, and
* physical token or magnetic cards that are actually inserted into a remote computer or terminal and "read" [Ref. 17:p. 49].

1. Host Computer Security Software

Resident on the host computer, this method utilizes a password system that is relatively easy to use. The user at the remote site must first enter his password, which is then transmitted through to the security software for validation. If incorrect, the password is rejected, and the remote user is blocked from further access.

In theory, a password system is relatively secure. In practice, it is a highly vulnerable approach. Passwords are generally widely known among the staff; some people even go as far as taping their password to the sides of the computer terminal. It is a simple matter for outsiders to obtain a password from friends within the organization and break into the system, resulting in theft of information or damage to data. If a password system is selected or already in use, it is important to change the password at least once a month, preferably once a week. However, keep in mind that passwords are child's play for computer criminals, particularly if the password is an actual word rather than an arbitrary string of letters and numbers. Computer thieves use simple spelling checkers to randomly generate almost an infinite number of words until they finally break in [Ref. 17:p. 49].

2. Encryption

The encryption method generates an unreadable version of a data stream. Encryption systems are available as hardware, software, or a combination of the two. In order to "crack the code" a data thief must have a great deal of time and access to some heavy computing power. This method is best exemplified by the Navy's traditional secure data communication system, Secure Telephone Unit III (STU-III).

3. Call-Back

The highly publicized, sometimes spectacular computer break-ins in the 1980s fueled the development of the call-back system. Today, the majority of the network security devices on the market are call-back systems. They work in the following way: when the remote user dials in, the call-back unit intercepts the call; the user then inputs a code or access number which the call-back unit checks against its library of authorized users; the host computer then calls back the user at an authorized phone number; finally, the user signals back and is allowed access to the computer [Ref. 17:p. 50].

Call-back systems offer many advantages for the system administrator. They are considered among the more secure systems on the market, and they are cheaper than using leased lines and encryption devices. According to some estimates, encryption can cost as much as 50 percent more than call-back devices. [Ref. 18:p. 50]

The call-back system does have its disadvantages, also. Telephone costs are higher because the caller assumes the cost when the system returns the call. However, the call-back system is compatible with less expensive telecom options such as Wide Area Telephone Service (WATS) and would be a plus for military customers.

4. Handheld Password Generators

This device, used primarily when a call-back is impossible or undesirable, has a unique encryption key tied to the user's personal identification number (PIN). When challenged by the network access control device, the handheld device generates a unique password that the user then enters into his PC or terminal; if correct, the user is allowed use of the host computer. [Ref. 17:p. 51]

5. Physical Tokens

The token system has less security than the four systems previously discussed. Token devices are magnetic cards that are inserted into a reader when requested by the host computer. If correctly authenticated the user is allowed access. If the card is lost or stolen a data thief could easily access the system. Thus, lost cards must be reported immediately so they can be disabled [Ref. 17:p. 51].

C. NATIONAL SECURITY AGENCY'S REQUIREMENT

The National Security Agency (NSA) requires that all information sent over military satellite communications channels be encrypted, regardless of its classification. The STU-III, an

encryption unit that encodes and decodes transmissions, meets this requirement and is the minimum level of security in place on all INMARSAT and cellular systems in use by the Navy today. Encryption codes are maintained at the top secret level and are changed every day for added security. Several commercial communication systems have installed some of the other optional features described above, and use them with some success. However, it appears prudent that the Navy use only the STU-III until the other security methods are approved by the NSA for Navy use.

V. DECISION CRITERIA FOR SYSTEM SELECTION

A. DATA RATE AND CLARITY

One of the primary factors involved in determining which system will meet the needs of the fleet is the rate at which it can send and receive data. Modems are the mechanical devices used to translate data. When a modem sends, it translates computer data into a form suitable for transmission over normal, voice-grade telephone lines. The majority of today's modems transfer data at rates between 2400 and 9600 baud; rates above 9600 are in development but are more expensive because they require special shielding from outside interference and expensive modulation and transmission equipment. [Ref. 20:p. 58]

When transmitting digital data, it is necessary to transmit numerous frequency changes and pulse lengths per second. Attenuation distortion describes the extent to which a signal traveling through a channel is affected as the frequency of the signal changes. The higher the data rate, the more changes per second the channel must handle. The ability of a channel to handle these changes is called high-frequency response [Ref. 7:p. 138].

Envelope delay distortion occurs because the amount of signal delay is not constant at a particular frequency. High-frequency signals are delayed differently from low-frequency signals. Since data signals are transmitted pulses, it is important that a channel preserve the pulse shape. In a channel with excessive delay distortion, various parts of the pulse arrive at different times

and cause the reception of a distorted version of the original pulse.

High data rates such as 9.6 kbit/s on voice grade circuits require maximum protection against these impairments because higher frequencies demand more power and are more susceptible to attenuation loss and antenna presentation angles [Ref. 14:p. 113]. To combat this problem, modem manufacturers maximize the differences between various pulse shapes. A signal that uses four voltage levels to define 2 bits per pulse is more resistant to noise and harmonic distortion than one that uses eight levels to define 3 bits per pulse. [Ref. 7:p. 202]

Another phenomenon exacerbated by delay is echo. The usual connection between a local telephone and the long-haul network is two-wire; that is, the same pair of wires carries sending and receiving signals. All long-haul trunks are four-wire, with separate pairs for the two transmission directions. Imperfect matching at the two-wire/four-wire junction can result in a portion of a speaker's transmission being reflected back to the speaker and can be very annoying. Echo suppressors have been used successfully to combat the effect, but the problem still remains to a small extent.

Finally, when long file transfers are performed, the accuracy of the transmission must be very high, so minimizing noise and harmonic distortion is also critical to data transmission because these impairments interfere with accurate reproduction of the transmitted pulse shapes. Once these impairments change the

original signal shape, a modem receiver is unable to recreate the signal shape regardless of its sophistication. To combat this the normal technique is to encode the data in order to detect transmission errors with very high probability and then to initiate a retransmission of the block containing the errors. When a satellite link is used, retransmissions are delayed by the path delay, thus the path is idle for some periods and the overall efficiency is reduced. Path delay can be overcome by pipelining the data flow; that is, by continuing to transmit continuous data streams until the receipt of a retransmission request, at which point the data stream is broken to insert a retransmission of an old block of data. While pipelining can be achieved relatively easily, it contributes to the delay disadvantage of satellite data transmissions [Ref. 17:p. 53].

Thus, the two most important criteria to consider when selecting the transmission mode are rate of data transfer and clarity. The faster the data rate the shorter the transmission time and lower cost for system access. However, with the increased rate of data transfer so comes the likelihood of errors incurred during transmission. Acknowledging that fact, both systems have demonstrated their reliability for clarity and error free transmissions during fleet and operational use [Ref. 16].

B. LIMITATIONS ON USAGE IN PORT AND UNDERWAY

Currently, ships at sea can only transmit logistics data to the supporting shore establishment via mail or the Navy telecommunications system. However, fleet satellite communication

channels can be very congested, especially during fleet exercises when logistics data is restricted/purged from the system. Smaller ships in port are inadequately supported with telephone lines at the pier; thus, communications with the local supply center are severely restricted. The last-resort line of communication with the local supply center is through on-site visits which often are difficult due to manpower availability.

The Fleet and Industrial Supply Center's choices for information exchange are limited to naval messages, letters, telephone calls or visits. During MINIMIZE, only letters (or NAVGRAMS) will get through. However, long delays in mail delivery may render the desired information obsolete. One practical solution is the cellular telephone, which can be used to communicate between the ship and the Fleet and Industrial Supply Center. Cellular telephones eliminate the reliance on in port access to telephone lines from the pier and the delays and disruptions at sea due to MINIMIZE conditions or congested fleet satellite channels. Also, a cellular system offers a cheaper alternative to INMARSAT when the ship is in port or within cellular communications distance from a shore data entry point.

It has been demonstrated that shipboard cellular phone systems can provide reliable communications with shore activities out to a range of 50 nautical miles (nm), and ship-to-ship communications to 35nm. [Ref. 13] These ranges are adequate considering that the operational tempo has been cut back and units are spending more time in port, in local operating areas, and underway in close

proximity battle group formations. This increased connectivity will increase the ship's productivity, improve casualty reporting (CASREP) status tracking, and allow faster requisition input with the Fleet and Industrial Supply Center. With this access to shore based information networks, the ship will be better able to query the supply system or to exchange data with the Defense Finance and Accounting Service for pay-related matters. The latter will result in improved pay record maintenance which directly impacts crew morale.

C. COST COMPARISON

In this section an overview of the cost to procure and operate each system will be presented. No data on installation cost, maintenance cost, or the costs of associated shipboard equipment such as IBM compatible computers, STU III phones, training, and test equipment will be presented because the author feels the associated cost differences would be insignificant between the two systems.

Approximate equipment costs are as follows:

INMARSAT-A	\$25-35K	antenna, RF cable, transceiver, amplifier, converters;
INMARSAT-B	\$25-40K	antenna, RF cable, transceiver, amplifier, converters;
INMARSAT-C	\$4-12K	antenna, RF cable, transceiver, amplifier,

		converters;
INMARSAT-M	$18-22K	antenna, RF cable, transceiver, amplifier, converters;
CELLULAR SYSTEM	$2-4K	antenna, RF cable, voice phone unit, for coastal or battlegroup use without MTSO;
CELLULAR SYSTEM	$750-850K	antenna, RF cable, phone unit, MTSO, cell site and auxiliary equipment.

Already installed onboard each ship are an IBM compatible computer, modem, STU-III and voice communication hand set. These items will be used with whichever system is selected.

The proposed equipment configuration for the fleet would be to have the mobile cellular system installed on every ship in the fleet. The more expensive version, with the MTSO, cell site, and auxiliary equipment, would be installed only on aircraft carriers and major amphibious units prior to deployments in conjunction with the INMARSAT-C system. This configuration allows all units to be in contact with shore installations virtually all the time.

Assuming equipment costs to be the midpoint of the range of values shown above, the total investment costs for 340 ships and 10 deployable major combatants are:

INMARSAT-C (140 times avg cost($10,000)) $1,400,000;
CELLULAR SYSTEMS (Coastal) (340 times avg cost($3000)) $1,020,000;
CELLULAR+ SYSTEMS (MTSO) (10 times avg cost($800,000)) $8,000,000.
We currently have 200 INMARSAT systems installed in the fleet and no cellular systems. In order to equip the fleet as proposed, 140 INMARSAT systems and 340 cellular systems would have to be initially procured.

The communication rate per minute is $0.70 for cellular telephone and $6.25 via INMARSAT. The INMARSAT value of $6.25 is for ship-shore communications and must be doubled for ship-ship communications because satellites must be accessed twice. Cellular system 12-month service contracts range from $29.99 to $199.99 depending upon the number of free local minutes, which range from 5 to 425 minutes, respectively [Ref. 14]. The $0.70 rate does not include the service contract cost.

Based on an average daily usage of 2.2 minutes per subscriber the net present value of each system is displayed in Table 2 [Ref. 3:p. 3 and 46]. The following assumptions were made in Table 2:

* An economic life of 8 years was used due to technology turnover;

* Interest rate of 7% was used, however calculations were also performed at 3% and 5% without any significant change to findings [Ref. 22:p. 9];
* Considering our current inventory of each system and our fleet projections on USN Ships, we would need to procure 140 INMARSAT and 340 cellular systems;
* Purchase price calculations are as shown above

  cellular: $1,020,000;

  cellular+:$8,000,000;

  INMARSAT: $1,400,000;
* Salvage value of 10 percent was used based on current sales receipts from several disposal sites selling electronic components [Ref. 21];
* Yearly expense is based on a average daily usage of 2.2 minutes per subscriber times 365 days a year times usage cost per minute;

* cellular and cellular+ costs = 340 ships times 2.2 minutes times $0.70 per minute times 365 days per year = $191,114; based on a total of 340 cellular configured ships,

* INMARSAT ship-to-shore costs = 340 ships times 2.2 minutes times $6.25 per minute times 365 days per year times 70% ship in port = $511,912. In addition, INMARSAT ship-to-ship costs = 340 ships times 2.2 minutes times $12.50 per minute times 365 days per year times 30% ship underway = $1,023,825, combined INMARSAT yearly expense is $1,535,737;

* Finally, with a 70% in port to 30% underway operating

schedule, 30% of the INMARSAT yearly expense is at the $12.50 rate.

Table 2 was constructed using the data and assumptions listed above and input into STORM, an integrated software package of quantitative modeling techniques for engineering and business problems [Ref. 19:p. 1]. In Table 2, the "Cellular" title refers to the basic cellular system for coastal and in port usage, "Cellular+" is the basis system plus the MTSO, cell site and auxiliary equipment for battle group operations.

TABLE 2

NET PRESENT VALUE COMPARISON

ROW LABEL	CELLULAR	CELLULAR+	INMARSAT
ECON LIFE	8	8	8
INTEREST	5	5	5
PUR PRICE	$1,020,000	$8,000,000	$1,400,000
SALV VALUE	$ 102,000	$ 800,000	$ 140,000
EXP YR 1	$ 191,114	$ 191,114	$1,535,737
EXP YR 2-8	THE SAME AS YEAR ONE FOR EACH CATEGORY		

Based of the information above the Net Present Cost (NPC) of each system is:

CELLULAR	$ 2,101,800
CELLULAR+	$ 8,675,600
INMARSAT	$10,489,000

The NPC indicates that the cellular system has a overall cheaper cost to procure and operate when in close proximity to land as well as in battle group formations at sea.

D. CAPABILITY TO HANDLE DATA AND VOICE COMMUNICATIONS

Cellular is optimized for voice service, but data can be transmitted by using a special modem. Cellular in its present

configuration is inefficient for handling short data messages. For instance, a 100-character message at 2400 baud takes approximately one-third of a second to transmit, but the call setup and take down time is on the order of eight or more seconds. Even though the message was transmitted in less than a second, depending on the rate schedule, the mobile unit would generally be billed for a minimum of either 30 seconds or one minute. However, a few carriers are beginning to offer a low cost, under-30 second dispatch rate [Ref. 10:p. 60].

INMARSAT is capable of low, medium, high or very high speed data transmissions (up to one megabyte per second). INMARSAT has no setup or takedown time periods so the user is only charged for actual time using the system as opposed to the cellular system. Even at the higher rates of data transmission it is doubtful that INMARSAT would be able to transmit data as economically as cellular due to the large price differential and average length of message transmissions.

Both systems offer excellent voice clarity and very few problems in understanding what is being said by the caller. In this area neither system has an advantage except in range where INMARSAT can be used over much greater distances [Ref. 15:p. 211].

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

In Chapter II, the origin of INMARSAT and its four major systems were explained and discussed. Of the four systems discussed INMARSAT-C has the most potential for use in the US Navy fleet for transmitting non-tactical information. This system was tested by NAVELEX in 1991 and the results were very favorable for using INMARSAT in military communication scenarios since it offers minimal interference with existing shipboard communication systems. FLEETSAT was tested in 1991 also, however, FLEETSAT performed rather poorly in that it lack the ability to easily adapt to PC interface, lack of channel capacity and shipboard assets (terminals) and finally the great cost it would of taken to expand the system due to engineering constraints were all negative factors against its choice.

In Chapter III, the history of the cellular telephone industry was discussed, and the major components of a cellular system were identified and explained. The cellular telephone was also tested in 1991 by NAVELEX and the results were very favorable for use in a coastal environment as well as on the open ocean when properly configured.

Chapter IV discussed several security options available to both systems, but went on to state that the only one currently accepted by the National Security Agency is the STU-III.

In Chapter V the net present value of both systems were presented with the cellular system assessed to be the cheaper to

procure and operate despite having a larger initial cost. Voice and data clarity were discussed with the advantage going to the cellular system primarily due to its completely digital components. With the great availability of cell sites in the continental United States and the per minute rate of $0.70, the cellular system is also an ideal backup when scarce telephone landlines are congested or in use when in port. Finally, both systems have the capability of transferring data at least at the 9600 baud rate.

B. CONCLUSIONS

While both systems discussed in this paper have considerable advantages, the author feels the cellular telephone system should be the primary system used by the Navy for the following reasons. The system is relatively inexpensive; offers a versatile network control and management capability; has a radio range that is adequate for ships operating in local operation areas, in port and in close proximity battle group formations, which is where at least 70% of a ships time is spent, is secure voice/data communication compatible; and it can be used in conjunction with INMARSAT in battle groups, where cellular telephone systems would handle the intra-battle group communications and INMARSAT would handle the long range (greater than 50 nautical miles) communications.

While not recommended, INMARSAT offers the following capabilities. The system offers global coverage underway and in port, the Navy will not have to build any expensive earth stations because they are already owned and maintained by COMSAT signatories (The signatories are responsible for the connection to terrestrial

communications). The system requires virtually no preventive maintenance and what preventive maintenance that is required would be very similar to that already performed by technicians onboard ships having existing satellite systems.

Finally, the cellular telephone system provides the Navy with a commercially available global communications system with secure voice and voice grade data capability. It uses standard state-of-the-art off-the-shelf equipment with a proven track record of high reliability. The system could also off-load administrative traffic from the UHF Fleet SATCOM system which is currently overburdened.

C. RECOMMENDATIONS

This author recommends that all ships in the United States Navy fleet be equipped with the cellular telephone system and that all large major battle group units (i.e., CV, CVN, LHA, LPH, AFS) be equipped with INMARSAT also. With units equipped as stated above, all Commanding Officers and Supply Officers can have the latest logistics information available to them in a near real time environment. This capability is one that ship's company has desired for a long time, but the technology has always been just over the horizon in terms of cost and practicality.

APPENDIX A

LIST OF ABBREVIATIONS

ACTS	ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE
BPS	BYTES PER SECOND
BPSK	BINARY PHASE SHIFT KEYING
CLF	COMBAT LOGISTIC FORCE
COMSAT	COMMUNICATIONS SATELLITE CORPORATION
CPSK	COHERENT PHASE SHIFT KEYING
DCE	DATA CIRCUIT TERMINATING EQUIPMENT
DTE	DATA TERMINAL EQUIPMENT
EGC	ENHANCED GROUP CALL
FDMA	FREQUENCY DIVISION MULTIPLE ACCESS

FEC	FORWARD ERROR CORRECTION
FLEETSATCOM	FLEET SATELLITE COMMUNICATION
GSO	GEOSTATIONARY ORBIT
GPS	GLOBAL POSITIONING SYSTEM
KBPS	KILO BYTES PER SECOND
INMARSAT	INTERNATIONAL MARITIME SATELLITE
INTELSAT	INTERNATIONAL TELECOMMUNICATIONS SATELLITE ORGANIZATION
MARECS	EUROPEAN SPACE AGENCY MARITIME SATELLITES
MARISAT	MARITIME COMMUNICATIONS SATELLITE SYSTEM
MES	MOBILE EARTH STATION
MSA	METROPOLITAN STATISTICAL AREA
MTSO	MOBILE TELEPHONE SWITCHING OFFICE
PC	PERSONAL COMPUTER

RCC	RADIO COMMON CARRIER
RF	RADIO FREQUENCY
SALTS	STREAMLINED ALTERNATIVE LOGISTICS TRANSMISSION SYSTEM
SATCOM	SATELLITE COMMUNICATION
TDM	TIME DIVISION MULTIPLEXING
TDMA	TIME DIVISION MULTIPLE ACCESS
TYCOM	TYPE COMMANDER
UHF	ULTRA HIGH FREQUENCY
VHF	VERY HIGH FREQUENCY

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